Polarforschung 54 (1): 37—41, 1984

Mass Balance Measurements at the Margin of the Inland Ice near Jakobshavn, West Greenland

By Henrik Højmark Thomsen*

Summary: In connection with hydropower investigations in West Greenland mass balance measurements have been carried out 1982/83 on the Inland Ice at Påkitsup ilordlia north-east of Jakobshavn. The mass balance was measured at seven stakes drilled into the ice at altitudinal intervals of 200 metres from 300 m to 1500 m a. s. l. The measurements show that mass balance conditions in the Jakobshavn area must have been abnormally positive for the 1982/83 hydrological year.

Zusammenfassung: Massenbilanzmessungen wurden in den Jahren 1982/83 auf dem Inlandeis am Påkitsup ilordlia, nordöstlich von Jakobshavn, im Zusammenhang mit der Entwicklung von Wasserkraft in Westgrönland unternommen. Die Massenbilanz wurde an sieben Pegeln gemessen, die in Höhenabständen von 200 m im Bereich von 300 bis 1500 m ü. N. N. in das Eis hinuntergebohrt waren. Die Messungen deuten darauf hin, daß die Massenbilanzbedingungen im Jakobshavn-Gebiet im Hydrologischen Jahr 1982/83 außergewöhnlich positiv waren.

INTRODUCTION

Since the mid-1970s there has been great interest in developing hydropower in Greenland. Many of the basins proposed for hydroelectric installations are connected to the Inland Ice and a great part of the runoff is made up by meltwater from the ice sheet.

Glaciological investigations have been started by the Geological Survey of Greenland (GGU) at different locations in West Greenland as a part of a two-year programme for mapping the hydroelectric potential in areas proposed for local hydropower projects (WEIDICK & THOMSEN, 1983a, 1983b). The present programme is supported by the EEC's European Fund for Regional Development and terminates in March 1984.

One of the localities is a basin at Påkitsup ilordlia north-east of Jakobshavn (Fig. 1) where mass balance measurements were started in August 1982. The ice-free part of the basin lies about 25 km south of the starting point of the EGIG route (Expedition Glaciologique Internationale au Groenland). The stake network established in 1982 crosses the EGIG route at about 1300 m a. s. l.

The measurements have been used for testing a mass balance model under development within GGU. The model is a natural development from the regional ablation model described by BRAITHWAITE (1980).

INVESTIGATION AREA

The ice-free part of the drainage basin at Påkitsup ilordlia lies between 69°25'N to 60°32'N and 50°05'W to 50°20'W (Fig. 2). The basin excluding its Inland Ice sector, covers an area of 33,6 km² and is situated at about 200 to 600 m a. s. l. Adjoining this area to the east is a sector of the Inland Ice. The size of the ice-covered drainage area is at present unknown because of the very limited knowledge about surface topography and sub- and englacial meltwater drainage in this part of the Inland Ice. Estimation of the size of the ice-covered drainage basin is at present under study, based on satellite data (THOMSEN, 1983) and radio-echo soundings are planned.

*Dr. Henrik Højmark Thomsen, Geological Survey of Greenland, Øster Voldgade 10, DK-1350 Copenhagen K (Denmark).

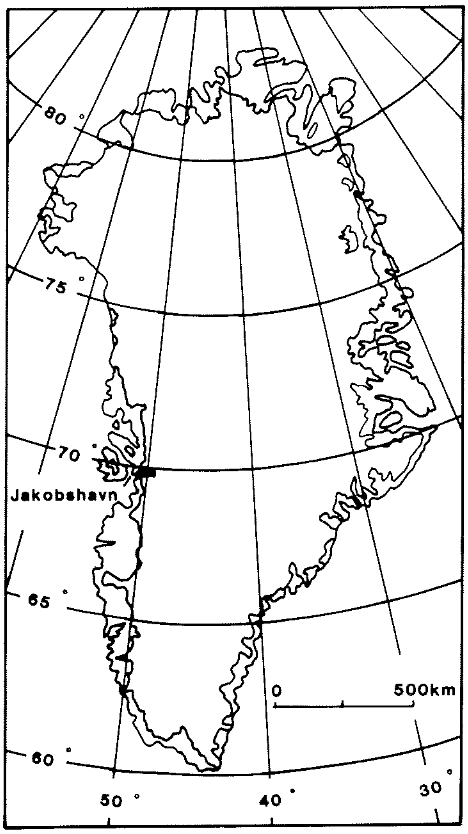

Fig. 1: Location of the investigation area north-east of Jakobshavn, West Greenland.

Abb. 1: Lage des Untersuchungsgebietes nordöstlich von Jakobshavn, Westgrönland.

The topography of the ice-free area splits up the margin of the Inland Ice into a number of smaller lobes. The ice lobes in the basin end at an altitude from 200 to 350 m a. s. l.

The surface of the Inland Ice in the area is very irregular, made up by gullies and crevasses at altitudes up to about 700 m a. s. l. At altitudes above 700 m, the surface is more even and can be described as an undulating plain.

FIELD WORK

Stakes for measuring the mass balance on the Inland Ice at Påkitsup ilordlia were established in August 1982. The stakes were visited in May 1983 and in August 1983 to measure the balance during the winter and summer.

The investigations were carried out as short visits by helicopter. The size and accessibility of the area create problems for establishment of measuring points. At lower altitudes the crevassed surface of the ice makes it difficult to land safely with a helicopter, in higher altitudes, where the surface is more even, there are problems with navigation and exact determination of the positions of measuring points, as no nunataks or other marked points exist to help locate the measuring points.

Seven stakes were drilled into the ice in August 1982 (stakes 3.0, 5.0, 7.0, 9.0, 11.0, 13.0 & 15.0), (Fig. 2). The starting point of the stake network is situated on the glacier 1GE07001 ending in the lake proposed as a reservoir for the hydropower project under investigation. The stakes are placed at intervals of 200 m altitude, from 300 to 1500 m a. s. l. Their altitudes being determined by the altimeter installed in the helicopter. The location of the stakes at the various altitudes is largely determined by the possibility of landing safely with the helicopter and moving in the terrain.

The stakes are aluminium tubes with an outside diameter of 32 mm drilled into the ice with a lightweight motor drill.

The measured changes refer to changes in elevation of the glacier surface in relation to the stakes. These surface changes are converted into water equivalent on the basis of density measurements in nearby snowpits and by assuming an ice density of 900 kg/m^3.

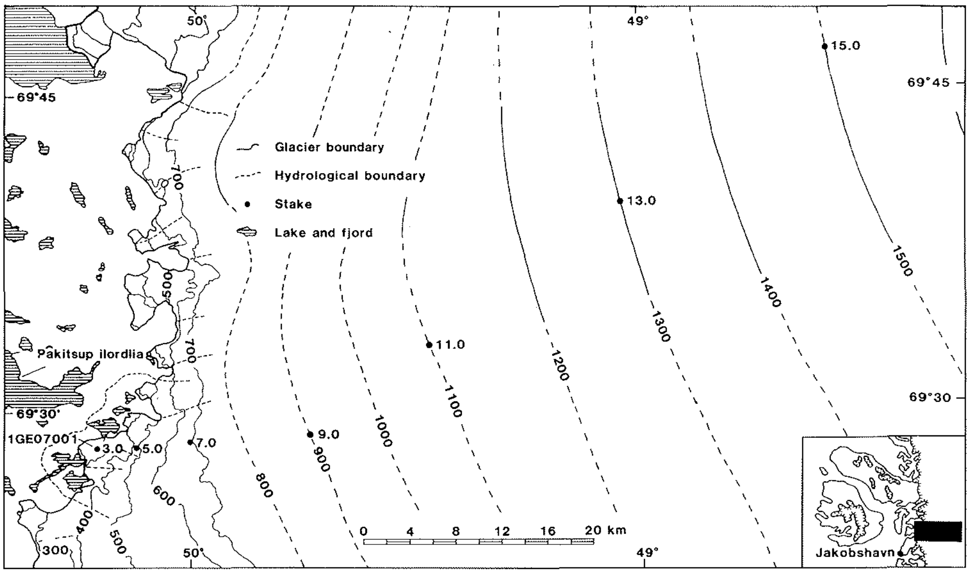

Fig. 2: Map of the Inland Ice at Pâkitsup ilordlia north-east of Jakobshavn. Positions of stakes are shown.

Abb. 2: Inlandeis am Pâkitsup ilordlia nordöstlich von Jakobshavn. Die Positionen der Pegel sind markiert.

RESULTS

The stakes were re-visited for the first time on 12 May 1983. One stake (stake no. 13) was not found.

The snow cover on the glacier was very patchy at altitudes up to about 500 m a. s. l., being mainly confined to drifts in gullies an crevasses. At altitudes over 700 m a. s. l. the snow cover was more or less continuous. Density measurements in snowpits at the rest of the stakes, showed a very uniform density, varying from 330 kg/m^3 to 380 kg/m^3 with a mean value of 360 kg/m^3. There were no signs of surface mel-

Stake	Elevation m a. s. l.	Mass changes 15/8 82 — 12/5 83	Transient balance 15/8 82 — 12/5 83	Mass changes 12/5 83 — 11/8 83	Transient balance 12/5 83 — 11/8 83	Annual balance 15/8 82 — 11/8 83
3.0	300	—423	—423	—2322	—2322	—2745
5.0	500	—306	—306	—1710	—1710	—2016
7.0	700	(+300) —306	— 6	(— 300) — 567	— 867	— 873
9.0	900	(+429) — 90	+339	(— 429) — 228	— 657	— 318
11.0	1100	(+577) —108	+469	(— 351) (+ 50)*	— 301	+ 168
13.0	1300	·/.	·/.	·/.	·/.	·/.
15.0	1500	(+502) — 36	+466	·/.	·/.	·/.

Tab. 1: Mass changes and balances 1982/83 for stakes on the Inland Ice at Pâkitsup ilordlia north-east of Jakobshavn. Figures in brackets refer to snow and those without brackets refer to ice. Units are mm w. e. for mass changes and balances. + Refreezing in snow, ·/. Stake not found.

Tab. 1: Änderungen der Massenbilanz und spezifische Massenbilanzen 1982/83 für Pegeln auf dem Inlandeis am Pâkitsup ilordlia, nordöstlich von Jakobshavn. Zahlen in Klammern verweisen auf Schnee, Zahlen ohne Klammern auf Eis. Einheiten sind mm (Wasserwert) für Änderungen der Massenbilanz und spezifische Massenbilanzen. + Eisablagerung im Schnee, ·/. Pegel nicht gefunden.

ting at the time of the visit and only very few or no thin ice lenses were observed in the snow cover, and there was no superimposed ice. From these observations it is reasonable to conclude that the observed snow cover distribution in the area is due to wind drifting.

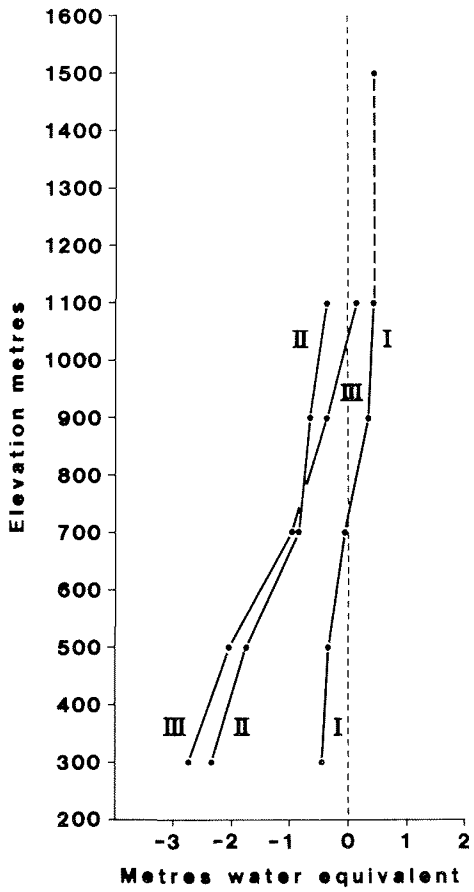

Fig. 3: Mass balance in relation to elevation on the Inland Ice at Pâkitsup ilordlia north-east of Jakobshavn.
I: Transient balance (15 August 1982 — 12 May 1983), II: Transient balance (12 May 1983 — 11 August 1983), III: Annual balance (15 August 1982 — 11 August 1983).

Abb. 3: Massenbilanz gegen Seehöhe auf dem Inlandeis am Pâkitsup ilordlia nordöstlich von Jakobshavn.
I: Änderung der Massenbilanz (15. August 1982 — 12. Mai 1983), II: Änderung der Massenbilanz (12. Mai 1983 — 11. August 1983), III: Jahresbilanz (15. August 1982 — 11. August 1983).

The mass changes and transient balance for the period 15 August 1982 to 12 May 1983 are shown in Tab. 1. It can be seen that some melting of ice has occurred in the period corresponding to 423 mm of w. e. at an elevation of 300 m a. s. l. and 36 mm of w. e. at an elevation of 1500 m a. s. l.

The stakes were visited for the second time 11 August 1983. Two stakes (nos. 13.0 and 15.0) were not found.

The mass changes and balance for the period 12 May to 11 August 1983 are shown in Tab. 1. The snow cover was melted away at altitudes up to 900 m a. s. l. At stake 11.0 at an elevation of about 1100 m a. s. l. the glacier surface was still snow covered. The stake reading at stake 11 shows that snow corresponding to 351 mm of w. e. had melted in the period. Through density measurements it was found that 50 mm of w. e. were retained in the snow cover due to refreezing.

DISCUSSION

The mass balance in relation to elevation is shown in Fig. 3. From the curves it can be seen that the annual equilibrium line altitude was around 1030 m a. s. l.

It should be noted that the balance figures represent single stake readings in the individual elevations. In the present work there has been no attempt to estimate the representivity of the stake readings, but earlier studies give an order of magnitude. BAUER (1961) discusses the representivity of the stake readings at EGIG Camp IV at 1000 m a. s. l., where the standard single stake was supplemented by five auxillary stakes. The mean ice ablation for the six stakes was -1.52 m of ice (from 7 June to 8 August) with a standard deviation of 0.24 m, i. e. 16 percent of the mean. BRAITHWAITE (1983) shows from mass balance measurements at Qamanârssûp sermia, that separate ablation measurements within a distance of a few metres can vary up to 17 per cent of the mean ablation because of errors in measurements and differences in local topography, particularly relief and exposure. It is therefore reasonable to assume that the true balance figures for the single elevations can vary about 15—20 per cent of the measured values.

Mass balance measurements have been carried out by A. BAUER in 1958/59 along the EGIG route (quoted in AMBACH, 1977, 1979), just north of the present investigation area. The present stake network crosses the EGIG route at an elevation of about 1300 m a. s. l. The net ice ablation for the period 25 July 1958 to 10 May 1959 shows a strange trend with less net ice ablation at lower altitudes compared to the net ice ablation at higher altitudes (AMBACH, 1977). AMBACH describes this trend as illogical from an energy point of view. From the ice data in Tab. 1 it can be seen that a similar trend was not found in the present investigation.

AMBACH (1977) quotes net ice ablation figures for the period 11 May to 11 August 1959 to be 2300 mm w. e. at 612 m, 1350 mm w. e. at 1013 m and 0 mm w. e. at 1241 m a. s. l. Comparison of the mass changes of ice for the period 12 May to 11 August 1983 (Tab. 1) shows that much less ice ablated in 1983 compared to 1959. The summer mean temperature (June—August) at the coastal station in Jakobshavn was 7.0 °C in 1959 and 5.4 °C in 1983.

The present measured mass balance data was used for testing a mass balance model (BRAITHWAITE & THOMSEN, 1984). The observed annual equilibrium line altitude (ELA) for 1982/1983 was around 1030 m a. s. l. while the corresponding value calculated by the model was 1090 m a. s. l. The mean ELA for the last 23 years is calculated to be 1300 m a. s. l. so the annual equilibrium line 1982/83 was very low. This shows that the mass balance conditions on this part of the Inland Ice must have been abnormally positive for the 1982/83 hydrological year.

ACKNOWLEDGEMENTS

This paper is published with the permission of the Director, The Geological Survey of Greenland. The project was supported by EEC's European Fund for Regional Development. I am grateful to the students Povl Frich and Jan Andsbjerg for help in the field. Roger J. Braithwaite helped me to prepare the manuscript.

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